(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 August 2001 (09.08.2001)

PCT

(10) International Publication Number
WO 01/58098 A2

(51) International Patent Classification[7]: H04L 12/56

(21) International Application Number: PCT/US01/03982

(22) International Filing Date: 7 February 2001 (07.02.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/500,189 7 February 2000 (07.02.2000) US

(71) Applicant: QUALCOMM INCORPORATED [US/US]; 5775 Morehouse Drive, San Diego, CA 92121-1714 (US).

(72) Inventor: SOLIMAN, Samir, S.; 11412 Cypress Canyon Park Drive, San Diego, CA 92131 (US).

(74) Agents: WADSWORTH, Philip, R. et al.; Qualcomm Incorporated, 5775 Morehouse Drive, San Diego, CA 92121-1714 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 01/58098 A2

(54) Title: POSITION DETERMINATION USING BLUETOOTH DEVICES

(57) Abstract: Apparatus and method to determine the position of a wireless device with Bluetooth capabilities. The method relies on transferring positioning information between devices using Bluetooth technology. If one of these devices knows its position (because it is in fixed position or because it has a GPS receiver or GPS sensor, or other ways of determining its own position), then this positioning information can be transferred to other devices in the RF proximity. In addition, triangulation using range measurements, and/or signal strength from several devices in the RF proximity can be used to determine the device position.

POSITION DETERMINATION USING BLUETOOTH DEVICES

BACKGROUND OF THE INVENTION

Field of the Invention

[1001] This invention relates to position determination, and has particular relation to position determination where the Global Positioning System (GPS) is not available.

Related Art

[1002] Bluetooth is a proposed Radio Frequency (RF) specification for short-range, point-to-multipoint voice and data transfer. Bluetooth is generally described at the Bluetooth Special Interest Group website, http://www.bluetooth.com, the disclosure of which, as of the filing date of this application, is incorporated herein by reference. Details of version 1.0B of the Bluetooth specification, published on December 1, 1999, particularly appear at http://www.bluetooth.com/developer/specification/core.asp, the disclosure of which is also incorporated herein by reference.

[1003] Bluetooth can transmit through solid, non-metal objects. Its nominal link range is from 10 cm to 10 m, but can be extended to 100 m by increasing the transmit power. It is based on a low-cost, short-range radio link, and facilitates ad hoc connections for stationary and mobile communication environments.

[1004] Bluetooth enables portable electronic devices to connect and communicate wirelessly via short-range, ad hoc networks. It is a universal radio interface in the 2.45 GHz frequency band that has gained the support of many wireless and computer equipment manufacturers. In order to function on a worldwide basis, Bluetooth requires a radio frequency that is license-free and open to any radio. The 2.45 GHz Industrial, Scientific and Medical (ISM) band satisfies these requirements, although it must cope with interference from other

devices which also use the same band. Bluetooth uses shorter data packets and higher hop rate, a combination that makes Bluetooth devices more immune to interference from other ISM devices and other sources of radio frequency.

[1005] According to market projections, Bluetooth technology will be built into hundreds of millions of electronic devices. This would make Bluetooth technology the fastest growing ever. It is estimated that before year 2002, Bluetooth will be a built-in feature in more than 100 million mobile phones and in several million other communication devices, ranging from headsets and portable PC's to desktop computers and notebooks. Bluetooth connects devices to the Internet both on the fixed and mobile infrastructure worldwide.

[1006] Bluetooth will enable users to connect to a wide range of computing and telecommunications devices without the need to buy, carry, or connect cables. It delivers opportunities for rapid communications with access points, ad hoc connections, and in the future, cable replacement, and possibly for automatic, unconscious, connections between devices. Bluetooth's power-efficient radio technology can be used with (see FIG. 1):

- Phones and pagers
- Modems
- Local area network (LAN) access devices
- Headsets
- Notebook, desktop, and handheld computers.

[1007] Bluetooth characteristics include:

- Operates in the 2.4 GHz Industrial-Scientific-Medical (ISM) band.
- Uses Frequency Hop (FH) spread spectrum, which divides the frequency band into a number of hop channels. During a connection, radio transceivers hop from one channel to another in a pseudo-random fashion.
- Supports up to 8 devices in a piconet (two or more Bluetooth units sharing a channel).
- Built-in security.

- Non line-of-sight transmission through walls and briefcases.
- Omni-directional.
- Supports both isochronous and asynchronous services; easy integration of Transmission Control Protocol/Internet Protocol (TCP/IP) for networking.
- Regulated by governments worldwide.

[1008] Bluetooth considers data exchange to be a fundamental function. Data exchange can be as simple as pushing a business card from a mobile phone to a PDA or as sophisticated as synchronizing personal information between a PDA and a PC. Bluetooth specifies these applications as well as other data exchange applications. Bluetooth uses the upper layer protocol (object exchange, or "OBEX") to implement these applications.

[1009] Communications between Bluetooth devices can be either peer-to-peer with each device being equal or between a master and slaves in a piconet configuration. A piconet is a small ad hoc network. It starts with two connected devices and may grow to include as many as many as eight devices. All devices in the piconet are synchronized to the master clock and hopping sequence.

[1010] Table 1 is a comparison between Bluetooth and cables:

Table 1 - Comparison between Bluetooth and cables		
	Bluetooth	Cable
Topology	Supports up to 7 simultaneous links	Each link requires another cable
Flexibility	Goes through walls, bodies, clothes	Line of sight or modified environment
Data rate	1 millisecond per average seek (MSPS), 720 Kbps	Varies with use and cost
Power	0.1 watts active power	0.05 watts active power or higher
Cost	Long-term $5 per endpoint	~ $3-$100/meter (end user cost)
Range	10 meters or less Up to 100 meters with power amplifier	Range equal to size. Typically 1-2 meters
Universal	Intended to work worldwide	Cables vary with local customs
Security	Very, link layer security, spread spectrum radio	Secure (it's a cable)

SUMMARY OF THE INVENTION

[1011] The idea is to install Bluetooth devices in places where access to GPS signals or any other means of finding position is prohibitive. Examples of these places include but are not limited to: Building lobbies, basements, inside elevators, inside parking garages, at bus stops, inside trains, inside buses, inside subway stations, etc. These Bluetooth devices will be provided by information about their geographical position by one of the following means:

1) It has a GPS receiver, or a GPS sensor, or it was able to obtain its position through a previous connection with another Bluetooth device.

2) It has access to network methods of calculating position.
3) It uses hybrid (GPS + network) methods to find its position.

[1012] The invention covers the following scenarios:

1) *Transferring positioning information between two Bluetooth devices in simple piconet (peer-to-peer scenario).* In this scenario if one device knows its own geographical position by some means such as having a GPS sensor or GPS receiver, network methods or hybrid methods. Radios are symmetric i.e.; connected radios can be master or slave.
2) *Transferring positioning information between a master Bluetooth device and a slave Bluetooth device in a piconet configuration.* A master can connect to seven simultaneous active slaves per piconet. In this scenario it is assumed that the master knows its own geographical position because:
   (a) it has a GPS receiver or a GPS sensor, or uses network methods or hybrid methods; or
   (b) it was able to obtain its position through a previous connection with another Bluetooth device.
3) *Two Bluetooth devices working in a client-server mode to determine the position of the client device.* The device with the server functionality receives measurements from the client, uses the measurements to calculate the position of the client, and then sends it back to the client.

[1013] One way to transfer (or communicate) position in Bluetooth is to define a Position Determination Service and use the Service Discovery Protocol (SDP). FIG. 2 demonstrates SDP client-server interaction. The service discovery mechanism provides the means for client application to discover the existence of services provided by server applications as well as the attributes of those services. The attributes of a service include the type or class of service offered and the mechanism or protocol information needed to utilize the service. The SDP does not provide a mechanism though for utilizing these services.

[1014] The SDP server maintains a list of service records that describe the characteristics of services associated with the server. A client may retrieve information from a service record maintained by the SDP server by issuing an SDP request.

[1015] If a Bluetooth device, or an application associated with the device, decides to use the Position Determination Service, it must open a separate connection to the service provider in order to utilize the service.

[1016] A single Bluetooth device may function as an SDP server and as an SDP client. There is a maximum of one SDP server per Bluetooth device. If multiple applications on a device provide services, an SDP server may act on behalf of those service providers to handle requests for information about the services that they provide. Similarly, multiple client applications may utilize an SDP client to query services on behalf of the client applications.

[1017] When a server becomes available, based on the RF proximity, a potential client must be notified by means other than SDP so that the client can use SDP to query the server about its service. Similarly, when a server leaves proximity or becomes unavailable for any reason, the client may use SDP to poll the server and may infer that the server is not available if it no longer responds to requests.

[1018] The Position Determination Service is an activity undertaken by a device that provides information describing the geographical position of the device. All the information about the service is contained within a single service record. The service record consists of a list of service attributes. Each service attribute consists of two components: attribute identity (ID) and attribute value. An attribute ID is used to distinguish each service attribute from other service attributes within a service record. The attribute value is a field whose meaning is determined by the attribute ID and by the service class of the service record in which the attribute is contained. A service class specifies each of the attributes IDs for the service class and assigns a meaning to the attribute value associated with each attribute ID.

[1019] Position information may consist of:

(a) *Latitude*: 21 bit field; covers the range -180 degrees to + 180 degrees with resolution of 10 meters;

(b) *Longitude*: 22 bit field; covers the range -90 degrees to +90 degrees with resolution of 10 meters; and

(c) *Altitude*: 11 bit field; covers the range –500 meters to 15833 meters with resolution of 8 meters.

[1020] Users have the option of setting up their Bluetooth devices to automatically establish a connection with another Bluetooth device as soon as they are within range. With automatic connection, two Bluetooth devices can exchange position data (latitude, longitude and altitude).

[1021] The term "Bluetooth", as used herein, is not limited to apparatus and methods which strictly comply with the official Bluetooth specification, but generally includes all apparatus and methods which provide information exchange over short-range radio links.

BRIEF DESCRIPTION OF THE DRAWINGS

[1022] FIG. 1 is a schematic view of prior art Bluetooth technology.

[1023] FIG. 2 is a block diagram prior art service discovery protocol.

[1024] FIG. 3 is a flowchart of a method according to the invention.

[1025] FIG. 4 is a flowchart of a client-server method according to the invention.

[1026] FIG. 5 is a schematic diagram of apparatus according to the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[1027] FIG. 3 is a flowchart of a method according to the invention. A first Bluetooth device (generally mobile) is located (302) within Bluetooth range of a second Bluetooth device (generally fixed). Position information is transmitted (304) from the second Bluetooth device, and is received (306) at the first Bluetooth device. The position of the first Bluetooth device is determined (308) from this information. Since Bluetooth is a short-range technology, the position of the first Bluetooth device may be considered to be the position of the second Bluetooth device.

[1028] Locating (310) a third Bluetooth device (or several third Bluetooth devices) within Bluetooth range of the first Bluetooth device provides additional accuracy. Each of the third Bluetooth devices transmits (304) additional position information, which the first Bluetooth device receives (306). The position of the first Bluetooth device is then determined using both the position information from the second Bluetooth device and the additional position information from the third Bluetooth device (or devices).

[1029] When such third Bluetooth devices are present, triangulation may be used to provide even more accuracy. A signal is either transmitted or received by the first Bluetooth device, and is measured (312) for signal delay, signal strength, or both. The measurement is then used, in conjunction with the position information and the additional position information, to determine the position of the first Bluetooth device. The measurement may be processed where it is made, or it may be transmitted to another Bluetooth device for processing.

[1030] A poll-response may be used. In this case, the first Bluetooth device transmits (314) a signal requesting another Bluetooth device to transmit position information. The second Bluetooth device receives (316) this signal before it transmits (304), in response to the signal, the position information.

[1031] FIG. 4 is a flowchart of a client-server method according to the invention. The first Bluetooth device makes at least one measurement (402) from at least one sensor. This typically is the signal delay or signal strength

referred to above, but may be a measurement of any parameter which will assist in positioning. The first Bluetooth device transmits (404) this measurement (or these measurements) to the second Bluetooth device, which receives (406) it. The second Bluetooth device processes (408) the measurement into position information, and transmits (410) the position information back to the first Bluetooth device, which receives it (412). This method is particularly desirable when, as often occurs, the mobile (first) Bluetooth device has limited processing abilities, and even more limited battery power, which is needed to exercise these processing abilities.

[1032] Sometimes it is better to invert the above architecture. Instead of having a single Bluetooth device receive position information from a plurality of other devices, it is better to have a plurality of Bluetooth devices receive position information from a single device. In this master-slave architecture, the first Bluetooth device is fixed, and the second Bluetooth device is mobile. One or more third Bluetooth devices are located (310) within Bluetooth range of the first Bluetooth device, and the first Bluetooth device transmits (304) position information to all of them. They all receive (306) this information, and determine (308) their position.

[1033] FIG. 5 is a schematic diagram of apparatus according to the invention. A first Bluetooth device (502), generally a fixed station, transmits position information to a second Bluetooth device (504), generally a mobile station. The second Bluetooth device may receive position information from one or more third Bluetooth devices (506), as described above. Also as described above, the architecture may be inverted, with the central "mobile station" (504) being the first Bluetooth device (which transmits the position information). The peripheral "fixed stations" (502), (506) then become the second and third Bluetooth devices.

[1034] The invention is thus seen to encompass at least three embodiments, namely, a Bluetooth device structured to transmit position information, a Bluetooth device structured to receive position information, and a method for using them together, singly or with other Bluetooth devices.

Other embodiments will occur to the ordinarily skilled artisan, and all such embodiments are considered to be within the spirit and scope of this invention.

Industrial Application

[1035] This invention is capable of exploitation in industry, and can be made and used, whenever is it desired to locate a position where the Global Positioning System (GPS) is not available. The individual components of the apparatus and method shown herein, taken separate and apart from one another, may be entirely conventional, it being their combination that is claimed as the invention.

[1036] While various modes of apparatus and method have been described, the true spirit and scope of the invention are not limited thereto, but are limited only by the following claims and their equivalents, and such are claimed as the invention.

WHAT IS CLAIMED IS:

CLAIMS:

1) A method for determining the position of a first Bluetooth device, wherein the method:

(a) includes the step of locating the first Bluetooth device within Bluetooth range of a second Bluetooth device; and

(b) is ***characterized in that*** it further includes the steps of:

(1) transmitting position information from the second Bluetooth device;

(2) receiving the position information at the first Bluetooth device; and

(3) determining the position of the first Bluetooth device from the position information.

2) The method of claim 1, wherein the method:

(a) includes the step of locating the first Bluetooth device within Bluetooth range of at least a third Bluetooth device; and

(b) is ***further characterized in that*** the method further includes the steps of:

(1) transmitting additional position information from each third Bluetooth device;

(2) receiving the additional position information at the first Bluetooth device; and

(3) determining the position of the first Bluetooth device from the position information and the additional position information.

3) The method of claim 2 wherein the method is ***further characterized in that*** the method further includes the steps of:

(a) making at least one measurement of signal delay, signal strength, or both signal delay and signal strength of a signal transmitted or received by the first Bluetooth device; and

(b) using the measurement in conjunction with the position information and the additional position information to determine the position of the first Bluetooth device.

4) The method of claim 1, *further characterized in that* the method further includes the steps of:

(a) the first Bluetooth device transmitting a signal requesting another Bluetooth device to transmit position information; and

(b) the second Bluetooth device receiving the signal from the first Bluetooth device before transmitting the position information.

5) The method of claim 1, wherein the method:

(a) further includes the steps of:

(1) the first Bluetooth device making at least one measurement from at least one sensor;

(2) the first Bluetooth device transmitting each measurement to the second Bluetooth device; and

(3) the second Bluetooth device receiving each measurement; and

(b) is *further characterized in that* the method further includes the steps of:

(1) the second Bluetooth device processing the measurement or measurements into position information;

(2) the second Bluetooth device transmitting the position information to the first Bluetooth device; and

(3) the first Bluetooth device receiving the position information.

6) The method of claim 1, wherein the method:

(a) includes the step of locating at least one third Bluetooth device within Bluetooth range of the second Bluetooth device; and

(b) is *further characterized in that* the method further includes the steps of:

(1) transmitting position information from the second Bluetooth device;

(2) receiving the position information at each third Bluetooth device; and

(3) determining the position of each third Bluetooth device from the position information.

7) A Bluetooth device, *characterized in that* the device includes:

(a) information on the position of the device; and

(b) means for transmitting the position information to another Bluetooth device.

8) The device of claim 7, wherein the device is *further characterized in that* it includes means for:

(a) making at least one measurement of signal delay, signal strength, or both signal delay and signal strength of a signal transmitted by the other Bluetooth device; and

(b) using the measurement in conjunction with the position information and the additional position information to determine the position of the other Bluetooth device.

9) The device of claim 7, wherein the device is *further characterized in that* it includes means for:

(a) receiving at least one measurement of signal delay, signal strength, or both signal delay and signal strength of a signal received by the other Bluetooth device; and

(b) using the measurement in conjunction with the position information and the additional position information to determine the position of the other Bluetooth device.

10) The Bluetooth device of claim 7, *further characterized in that*:

(a) the device includes means for receiving a signal from the other Bluetooth device requesting position information; and

(b) the means for transmitting the position information to the other Bluetooth device is structured to respond to the signal.

11) The Bluetooth device of claim 7, *further characterized in that* the device further includes means for:

(a) receiving a measurement from the other Bluetooth device;

(b) processing the measurement into position information; and

(c) transmitting the position information to the other Bluetooth device.

12) A Bluetooth device, ***characterized in that*** the device includes means for receiving information from another Bluetooth device on the position of the other Bluetooth device.

13) The device of claim 12, wherein the device is ***further characterized in that*** it includes means for:

(a) making at least one measurement of signal delay, signal strength, or both signal delay and signal strength of a signal transmitted by the other Bluetooth device; and

(b) using the measurement in conjunction with the position information and the additional position information to determine the position of the device.

14) The device of claim 12, wherein the device is ***further characterized in that*** it includes means for:

(a) receiving at least one measurement of signal delay, signal strength, or both signal delay and signal strength of a signal transmitted by the device; and

(b) using the measurement in conjunction with the position information and the additional position information to determine the position of the device.

15) The Bluetooth device of claim 12, ***further characterized in that***:

(a) the device includes means for transmitting a signal to the other Bluetooth device requesting position information; and

(b) the means for receiving the position information from the other Bluetooth device is structured to respond to a response to the signal.

16) The Bluetooth device of claim 12, ***further characterized in that*** the device further includes means for:

(a) making at least one measurement from at least one sensor;

(b) transmitting each measurement to a second Bluetooth device.

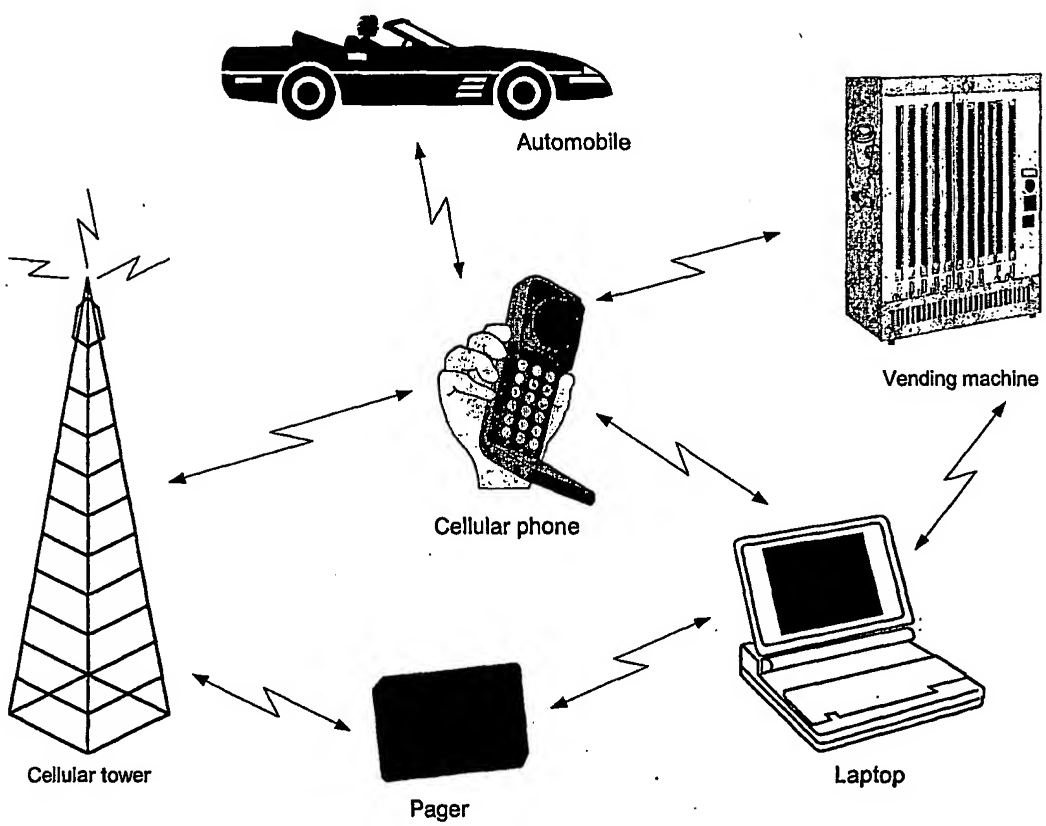

FIG. 1
PRIOR ART

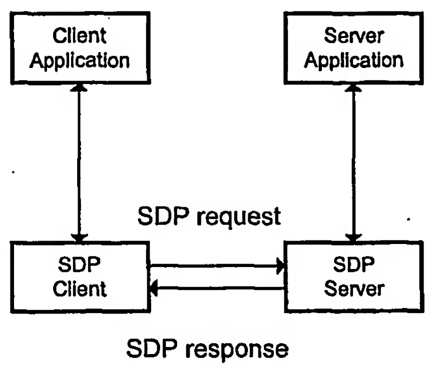

FIG. 2 - Service Discovery Protocol
PRIOR ART

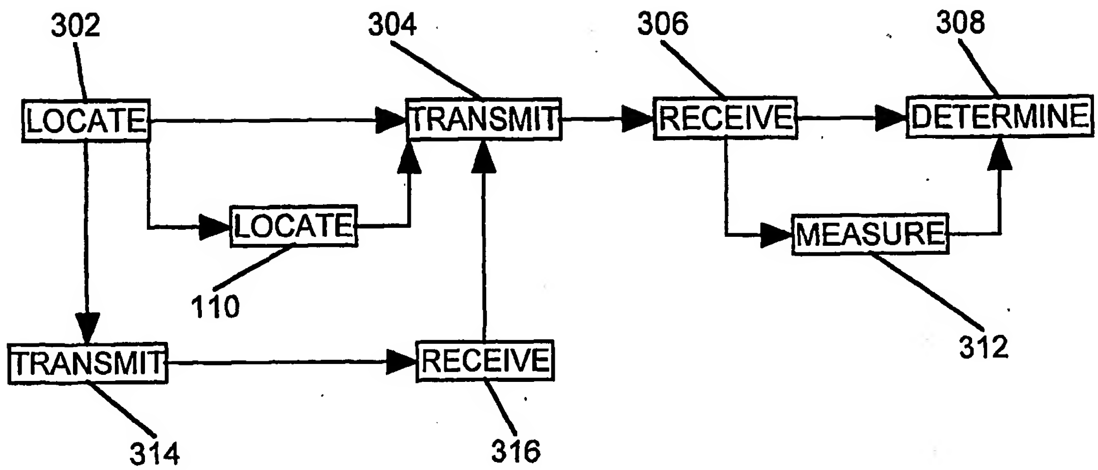

FIG. 3

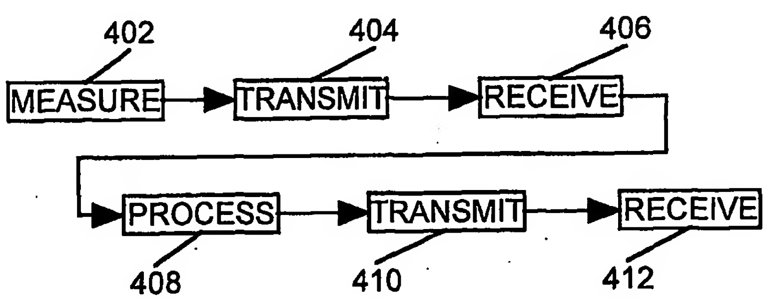

FIG. 4

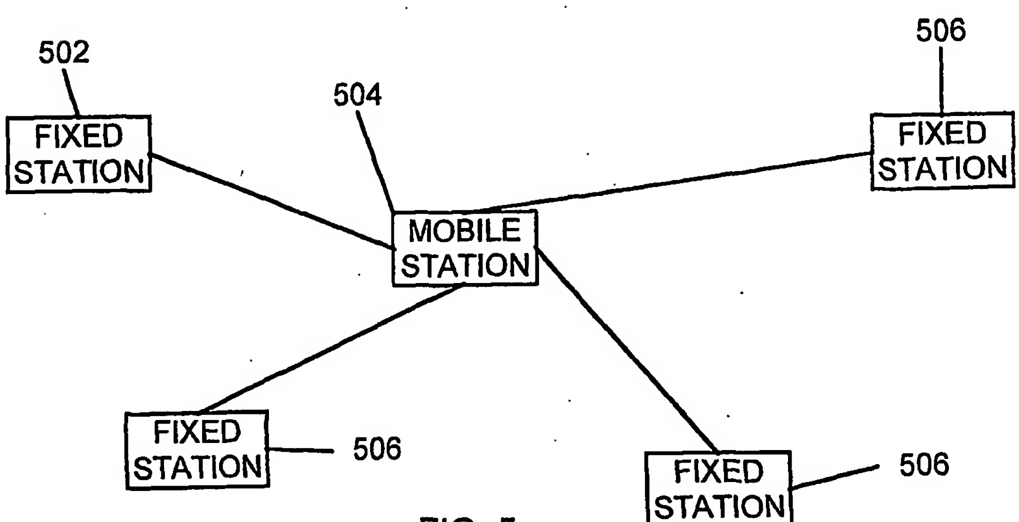

FIG. 5